THE SPECTRUM OF ARGON IV

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ABSTRACT. The spectrum of argon has been investigated under several experimental conditions in the near ultra-violet and visible regions. An examination of the data obtained enabled the extension of the analysis of the spectrum of the trebly ionised atom of argon into the visible and the near ultra-violet regions. A dozen terms have been newly discovered in the present investigation involving the classification of about 30 lines

INTRODUCTORY

Of the several spectra of argon, the analyses of A I[1] A II[2] and A III[3] were investigated by various workers—Meissner, Compton, Boyce, De Bruin and others. But, of the spectrum of trebly ionised argon, A IV, only a partial analysis was done by Boyce,[4] his investigation being confined to the very extreme ultra-violet vacuum grating region. With a view to further extending the analysis into the near ultra-violet and the visible regions, investigations on the spectrum of argon gas were undertaken from λ 2000 to λ 6000 under various experimental conditions and these enabled the detection of the prominent terms due to the $4p$, $4d$ configuration.

EXPERIMENTAL

The discharge tube employed for this work was just similar to that used with krypton.[5] The same general experimental arrangement and procedure were adopted with argon, an argon reservoir being substituted in place of that containing krypton. A diagram of the discharge tube, the drying system of calcium chloride and potassium hydroxide towers, the vacuum pump, and the gas reservoir with its attachment is represented in figure I. The gas was excited by passing a condensed discharge through the tube, between aluminium electrodes with the help of a transformer capable of giving 20,000 volts in the secondary. A small inductance was used in series with the secondary circuit to suppress the lines due to the residual air. Photographs of the spectrum under different stages of excitation were obtained by taking recourse to the usual methods of altering the capacity, the length of the series gap and the pressure of thegas inside the tube. A Fuess glass spectrograph and a Hilger large Litrow type of quartz spectrograph were employed to obtain the spectrograms.

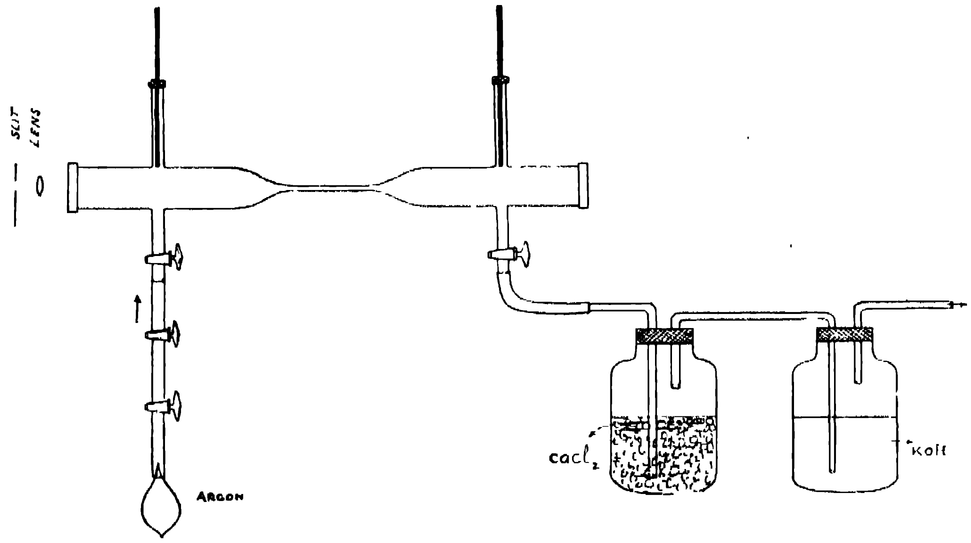

FIGURE I

PREDICTED TERMS

The characteristic terms of the spectrum of A IV predicted theoretically in accordance with the theory of Hund and Heisenberg are presented in Table I.

Out of these the fundamental $4s\,(^4P-{}^4D)$ $4s\,^4P-4p\,^4P$ multiplets, and some doublet terms due to the $4p$, configurations were identified already by the previous workers. In the present work some of the prominent terms due to the $4p$, $4d$ configurations have been detected.

TABLE I

Predicted Terms in Argon IV

Configuration. 4_1	4_2	4_3	4_4	5_1	5_2	5_3	5_4	5_5	6_1	Term Prefix.	Terms.
2	3									$4p$	^4S ^2D ^2P
2	2									$5s$	^4P ^2P ^2D ^2S
											^4D ^4P ^4S ^2F $^2D^a$ $^2P^b$
2	2									$5p$	^2D ^2P ^2S $^2P^a$
2	2									$4d$	^4F ^4D ^4P ^2G $^2F^a$ $^2D^a$ $^2G^b$
											^2F ^2D ^2P $^2P^a$ $^2S^b$
2	2									$6s$	^4P ^2P ^2D ^2S
1	4									sp^4	^4P ^2P ^2D ^2S

TABLE II

Multiplet Scheme in Argon IV

4p	$^4D_{\frac{1}{2}}$ 268·6	$^4D_{1\frac{1}{2}}$ 522·9	$^4D_{2\frac{1}{2}}$ 804·1	$^4D_{3\frac{1}{2}}$	$^4P_{\frac{1}{2}}$ 111·9	$^4P_{1\frac{1}{2}}$ 596·9	$^4P_{2\frac{1}{2}}$	$^4S_{1\frac{1}{2}}$
4s	285960	286228·8	286751·7	287555·8	289125·9	289237·8	289834·7	291748·7
$^4P_{\frac{1}{2}}$ = 250219 687·1	35740·7 (7)	36009·1 (10)			38905·9 (7)	39018·7 (12)		41529·4 (6)
$^4P_{1\frac{1}{2}}$ = 250906·6 1066	35053·6 (4)	35322·2 (10)	35845·1 (14)		38219·3 (12)	38331·2 (10)	38928·1 (10)	40842·1 (8)
$^4P_{2\frac{1}{2}}$ = 251972		34256·8 (3)	34719·7 (16)	35583·8 (16)		37765·8 (9)	37862·6 (15)	39776·7 (12)
$^2P_{\frac{1}{2}}$ = 256093·3					33032·6 (5)	33145·2 (5)		
$^2P_{1\frac{1}{2}}$ = 257348·9					31776·9 (4)	31889·7 (3)	32485·6 (8)	
$^2D_{1\frac{1}{2}}$ = 268171·4								
$^2D_{2\frac{1}{2}}$ = 268151·4								
a = 246616					42507·6 (1)	42623·6 (5)		
b = 259765		26464·9 (4)				29173·9 (8)	30068·6 (6)	31980·7 (2)
c = 253344	32615·8 (1)	32887·9 (2)				35890·9 (4)		
d = 256767	29193·7 (5)	29461 (2)						
e = 259306	26653·5 (6)	26923·3 (6)						
f = 262327	23635·1 (8)	23899·7 (6)						
g = 263327	22631·9 (2)	22904·1 (2)				25909·8 (7)		
h = 264678	21280·5 (3)	21548·7 (1)			24448·7 (3)			27072·5 (4)
i = 265440	20520·8 (2)	20790·0 (2)	21311·9 (2)					26305·6 (5)
j = 268813	17147·9 (5)	14417·0 (4)			20310·3 (1)	20425·3 (3)		
k = 269127	16836·0 (2)	17098·0 (5)						

TABLE II (*contd.*)

Multiplet Scheme in Argon IV

4p	$^2D_{1\frac{1}{2}}$	1411.2 $^2D_{2\frac{1}{2}}$	$^2P_{\frac{1}{2}}$	131·3 $^2P_{1\frac{1}{2}}$	$^2S_{\frac{1}{2}}$	$^2F_{2\frac{1}{2}}$	325·6 $^2F_{3\frac{1}{2}}$	A
4s	290256·5	291667·7	295674·5	295805·8	299563·2	304074·3	304399·9	29291424·5
$^4P_{\frac{1}{2}}$ = 250219 687·1	40037·1 (3)							
$^4P_{1\frac{1}{2}}$ = 250906·6 1066	39349·7 (4)	40761·1 (4)						40517·6 (3)
$^4P_{2\frac{1}{2}}$ = 251972	38284·6 (3)	39095·8 (6)						39449·9 (2)
$^2P_{\frac{1}{2}}$ = 256093·3	34162·5 (11)		39581·2 (9)	39713·5 (5)	43470·1 (4)			
$^2P_{1\frac{1}{2}}$ = 257348·9	32907·1 (6)	34318·8 (12)	38325·7 (7)	38457·9 (12)	42214·1 (3)			
$^2D_{1\frac{1}{2}}$ = 268171·4	38136·8 (12)	38064·8 (2)				36248·5 (14)		
$^2D_{2\frac{1}{2}}$ = 268151·4	38156·7 (6)	38085·1 (12)				35922·9 (3)	36248·5 (14)	
a = 24661								31660·6 (3)
b = 259765								
c = 253344								
d = 256767	33490·6 (1)							
e = 259306								
f = 262317								
g = 263327								
h = 264678	25578·5 (2)							
i = 265440								
j = 268813								
k = 269127								

ANALYSIS

A careful examination of the plates taken under different excitations made it possible to ascribe about a hundred lines as belonging to the trebly ionised atom of argon and of these, about 30 lines have entered into the extension of the multiplet scheme of argon suggested in this work. Many of the lines are rather broad and broader than those due to krypton under similar experimental conditions. This might probably be due to the smaller atomic weight of argon. The difficulty of measurement of the argon lines was therefore larger and the accuracy somewhat less than that obtained with krypton lines.

The working out of the analysis of A IV was comparatively easier than that of Kr IV as the differences involved are smaller and as the structure and the main intervals are known from the work of de Bruin and Boyce. A search was made for the pairs having the wave-number differences 268.6 and 111.9 cm.$^{-1}$ corresponding respectively to $4p\ (^4D_{\frac{1}{2}} - {}^4D_{1\frac{1}{2}})$ and $4p\ (^4P_{\frac{1}{2}} - {}^4P_{1\frac{1}{2}})$. The selections of the proper pairs from these was made by trying to extend the scheme with each of these pairs. Starting then with some of the cross differences, new levels could be detected. Thus a new level scheme was set up and shown in Table II which includes also the combinations identified by Boyce.

About a dozen levels have been thus newly identified and these are expected to be due chiefly to the *md* configuration. They are designated arbitrarily by the symbols a, b, c, etc., as it is practically impossible to make a more definite assignment or even to distinguish between the quartet and doublet terms. The proper value of even the inner quantum number of these levels cannot be defined unambiguously. The values suggested in certain cases are to be regarded as tentative. But it is believed that the levels themselves are all real. Table III shows the list of lines newly classified in the spectrum of argon IV.

TABLE III

Newly classified lines in Argon IV

λ (Sut.).	ν (vac.).	Classification	ν (Sut.).	ν (vac.).	Classification.
5938·01(2)	16836·0	$4p^4D_{\frac{1}{2}} - k$	3750·79(6)	26653·5	$4p^4D_{\frac{1}{2}} - e$
5847·03(5)	17098·0	$4p^4D_{1\frac{1}{2}} - k$	3713·19(6)	26923·3	$4p^4D_{1\frac{1}{2}} - e$
5830·04(5)	17147·9	$4p^4D_{\frac{1}{2}} - j$	3692·74(4)	27072·5	$2p^4S_{1\frac{1}{2}} - h$
5739·88(4)	17417·2	$4p^4D_{1\frac{1}{2}} - j$	3424·13(5)	29193·7	$4p^4D_{\frac{1}{2}} - d$
4922·50(1)	20310·3	$4p^4P_{\frac{1}{2}} - j$	3393·35(2)	29461·0	$4p^2D_{1\frac{1}{2}} - d$
4894·53(3)	20425·3	$4p^4P_{1\frac{1}{2}} - j$	3391·86(8)	29473·9	$4p^2P_{\frac{1}{2}} - b$

TABLE III (*contd.*)

Newly classified lines in Argon IV

λ(Sut.).	ν(vac.).	Classification	ν(Sut.).	ν(vac.).	Classification.
4871·78(2)	20520·8	$4p^4D_{1\frac{1}{2}}-i$	3324·78(6)	30068·6	$4p^4P_{2\frac{1}{2}}-b$
4808·66(2)	20790·0	$4p^4D_{1\frac{1}{2}}-i$	3157·60(3)	36660·6	$A-b$
4697·87(3)	21280·5	$4p^4D_{\frac{1}{2}}-h$	3125·98(2)	31980·7	$4p^4S_{1\frac{1}{2}}-b$
4690·9(2)	21311·9	$4p^4D_{2\frac{1}{2}}-i$	3065·11(1)	32615·8	$4p^4D_{\frac{1}{2}}-c$
4639·36(1)	21548·7	$4p^4D_{1\frac{1}{2}}-h$	3039·75(2)	32887·9	$4p^4D_{1\frac{1}{2}}-c$
4417·30(2)	22631·9	$4p^4D_{\frac{1}{2}}-g$	2985·04(1)	33490·6	$4p^4D_{1\frac{1}{2}}-d$
4364·80(2)	22904·1	$4p^4D_{2\frac{1}{2}}-g$	2785·30(4)	35890·9	$4p^4P_{1\frac{1}{2}}-c$
4229·81(8)	23635·1	$4p^4D_{\frac{1}{2}}-f$	2534·1(2)	39449·9	$A-4s^2P_{2\frac{1}{2}}$
4182·97(6)	23899·7	$4p^4D_{\frac{1}{2}}-f$	2467·3(3)	40517·6	$A-4s^2P_{1\frac{1}{2}}$
4089·04(3)	241[illegible]8·7	$4p^4P_{\frac{1}{2}}-h$	2351·8(1)	42507·6	$4p^2p_{\frac{1}{2}}-a$
3908·43(2)	25578·5	$4p^2D_{2\frac{1}{2}}-h$	2345·4(5)	42623·6	$4p^4P_{1\frac{1}{2}}-a$
3858·46(6)	25909·8	$4p^4P_{1\frac{1}{2}}-g$			
3800·42(5)	26305·6	$4p^4S_{1\frac{1}{2}}-i$			
3777·52(4)	26464·9	$4p^4D_{1\frac{1}{2}}-f$			

Term Values

The term values are determined through the identified lines on the basis of the term scheme set up by Boyce in adopting $4sP_{\frac{1}{2}}$ equal to zero. Table IV shows completely all the values of the energy states so far known.

TABLE IV

Term Values in A IV

Term.	Term Value. ν	δν	Term.	Term Value λ	δν
$4p^4D_{\frac{1}{2}}$	285960·2		A	291425·5	
		268·6			
$^2D_{1\frac{1}{2}}$	286228·8				
		522·9			
$^2D_{2\frac{1}{2}}$	286751·7		a	246616	
		804·1			
$^2D_{5\frac{1}{2}}$	287555·8		b	259765	
			c	253344	

TABLE IV (*contd.*)

Term Values in A IV

Term.	Term Value. ν	$\delta\nu$	Term.	Term Value. λ	$\delta\nu$.
$^2P_{\frac{1}{2}}$	289125·9	111·9	d	256767	
$^2P_{1\frac{1}{2}}$	289237·8	596·9	e	259306	
$^4P_{\frac{1}{2}}$	289834·7		f	262327	
$^2S_{1\frac{1}{2}}$	291748·7		g	263327	
			h	264678	
$^2D_{1\frac{1}{2}}$	290256·5	1411·2	i	265440	
$^2D_{2\frac{1}{2}}$	291667·7		j	268813	
$^2P_{\frac{1}{2}}$	295674·5	131·3	k	269127	
$^2P_{1\frac{1}{2}}$	295805·8				
$^2S_{\frac{1}{2}}$	299663·2				
$^2F_{2\frac{1}{2}}$	304074·3	325·6			
$^2F_{3\frac{1}{2}}$	304379·9				
$4s\,^4P_{\frac{1}{2}}$	250219	687			
$^4P_{1\frac{1}{2}}$	250906	1066			
$^4P_{2\frac{1}{2}}$	251972				
$^2P_{1\frac{1}{2}}$	256093·3	1255·6			
$^2P_{1\frac{1}{2}}$	257348·8				
$^2D_{1\frac{1}{2}}$	286171·4	20			
$^2D_{2\frac{1}{2}}$	268151·4				

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